

# Evaluation of Control Technologies in Underground Mines

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**Control Technologies for Diesel Vehicles in Underground Coal Mines**  
**Workshop Louisville, Kentucky, July 30, 2003**

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## Field Evaluations of Technologies

- Relatively complex projects involving mining industry, labor, government agencies, equipment manufacturers, ...
- Field vs. laboratory

	Field (prod. or isolated zone)	Laboratory
relevance	high	limited to fundamental research
scope	moderate to broad	limited to moderate
complexity	high	high
requirements	moderate to high	high
accuracy	low to moderate	moderate to high
replication	low to moderate	high

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## Short- vs. Long-term Field Evaluations

- Short-term evaluations
  - Emissions, installation and operational issues...
  - Short term commitment...
- Long-term evaluation
  - Emissions, installation and operational issues, reliability, durability, cost-benefit estimate, training...
  - Long term commitment

## Field Emissions Measurements

- Production Tests
  - Most representative but relatively complex, difficult to replicate, relatively inaccurate, expensive...
- Tailpipe Emissions
  - Simple, accurate, easy to replicate, inexpensive, but limited to couple steady-state operating conditions, incomprehensive...
- Isolated Zone
  - Bridge differences between tailpipe and production evaluations

## Long-term Field Evaluations of Control Technologies - DPFs

- Brunswick Mining and Smelting, New Brunswick (DEEP sponsored) - four heavy-duty retrofitted with DPF systems
- Stobie Mine, Sudbury, Ontario (DEEP sponsored) - three DPF systems retrofitted to heavy-duty vehicles and two DPF systems retrofitted to light-duty vehicles.
- Oxbow Mine, Colorado (Coal Partnership) - ECS DPF systems with on-board electrical regeneration retrofitted to EIMCO 975 supply hauler
- Sufco Mine, Utah (Coal Partnership) - DCL DPF with on-board electrical regeneration retrofitted to Wagner lube truck

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## Long-term Field Evaluations of Control Technologies - DPFs

- Buchanan Mine, Virginia (Coal Partnership) - 2 ECS DPF systems with on-board electrical regeneration retrofitted to Brookville Mining Equipment supply vehicle.
- Highland Mine, Kentucky (Coal Partnership) - ECS DPF systems with on-board electrical regeneration to A.L. Lee mini-trac
- ...

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## Field Evaluations of Control Technologies

- **Disposable filtration systems**

- Sufco Mine, Utah – Donaldson P604516 (high temperature media)
- Mettiki Mine, Maryland – Molish linen filter trial after wet scrubber (washable media)
- ...

- **Electronically vs. mechanically controlled diesel engines**

- Bagley et al. [2001]. Impact of Low-Emission Diesel Engines on Underground Mine Air Quality. Study conducted in salt mine in Louisiana.

- ...

## Short Term Field Evaluations of filtration systems

- Energy West, Deer Creek Mine, Huntington, Utah
- Stillwater Mining, Nye Mine, Nye, Montana

## Study at Deer Creek Mine, Huntington, Utah (February and May 2002)

- ✱ Study sponsored by Coal Partnership (BCOA, UMWA, and NIOSH)
- ✱ Collaborative effort of NIOSH PRL, Energy West, and Canyon Fuel Co., with active participation from UMWA and MSHA
- ✱ Tests were done in two stages: February and May 2002
- ✱ The tests were executed as tailpipe emissions and isolated zone measurements.

## Study at Deer Creek Mine, Huntington, Utah - Objectives

- ✱ Investigate the effects of engine fueling rate, size of torque converter and other engine/vehicle parameters on PM and gaseous emissions from the vehicles operated at high elevations
- ✱ Short-term evaluation of three diesel particulate matter filtration systems
  - ✱ Wagner water scrubbers several disposable filter elements from Donaldson and Baldwin (February and May)
  - ✱ DST system with disposable filter element (May)
  - ✱ NETT Pt catalyzed filter (May)

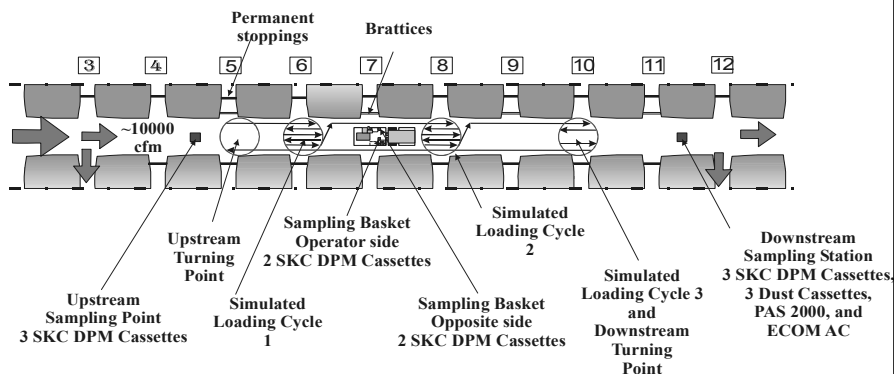
## Deer Creek Study (February 2002) – Method

- ✱ Tailpipe emissions
  - DPM emissions were measured using :
    - Filter samples for NIOSH 5040 carbon analysis
    - Elemental carbon using PAS 2000
    - Exhaust opacity using AVL DiSmoke 4000
    - Bacharach Smoke spot number using ECOM KL
  - Gaseous emissions (CO, NO, NO<sub>2</sub>, O<sub>2</sub>) were measured using ECOM KL
- ✱ Isolated zone
  - DPM conc. were measured using :
    - Filter samples for NIOSH 5040 carbon analysis
    - Elemental carbon using PAS 2000
  - Concentrations of CO, NO, NO<sub>2</sub>, O<sub>2</sub> in mine air were measured using ECOM AC

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## Isolated Zone: Contribution of the Vehicles to Concentrations of DPM and Gases in Air



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## Deer Creek Study (February 2002) - Findings

- The maximum fueling rate for the CAT 3306 PCNA engine as set by authorized Caterpillar service was found to be excessively high and resulted in an engine PM emissions significantly higher than that obtained by MSHA during sea level certification tests.
- The PM emissions from properly tuned vehicles were substantially lower than those obtained during MSHA certification.

## Deer Creek Study (February 2002) - Findings

- The PM emissions rate of the vehicles powered with an engine adjusted according to manufacture specifications and equipped with water scrubber and paper filter were measured to be higher than the target compliance level of 2.5 g/hr.
- The testing resulted in the modifications of the certain components of the filtration systems
  - water separator
  - water level limit hole in the water scrubber
- This modifications extended significantly filter life and improved efficiency of the systems.

## Deer Creek Mine (May 2002): Wagner Water Scrubber System, Donaldson Filter Elements



## Deer Creek Mine (May 2002): DST System and M30 Filter Element





## Deer Creek Mine (May 2002): Catalyzed DPF retrofitted to Deutz BF6M1013CP



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## Deer Creek Study (May 2002) – Findings

- Some of the filtration systems were found to have potential to reduce concentrations of total carbon under the current standards for metal/nonmetal underground mines ( $160 \mu\text{g}/\text{m}^3$  of TC):
  - The total carbon concentration of  $26.4 \pm 11.9 \mu\text{g}/\text{m}^3$  was measured in mine air when the vehicle equipped with Donaldson “Blue” filter was operated in the zone
  - The total carbon concentration of  $104.7 \pm 15 \mu\text{g}/\text{m}^3$  was measured in mine air when the vehicle equipped with DST M30 filter was operated in the zone
  - The Donaldson “Blue” and DST PAAS M30 filter elements were found to remove DPM measured as total carbon in excess of 95%
- The other tested filter elements offered significantly lower reductions in DPM emissions

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## Deer Creek Study (May 2002) - Findings

- After several minutes of operating vehicle retrofitted with diesel particulate filter (DPF) with platinum based catalyst over test cycle, the concentrations of nitrogen dioxide (NO<sub>2</sub>) in isolated zone exceeded ceiling levels of 5 ppm
- This tests show that there is potential for introduction of secondary health hazard with implementation of control technologies
- On May 31<sup>st</sup>, 2002 MSHA issued program information bulletin (PIB P02-4) informing mine operators of a potential health hazard caused by currently available platinum-based catalyzed DPFs

## Evaluation of Control Technologies at Stillwater Nye Mine, Nye, Montana

- Study sponsored by Metal/Nonmetal Partnership
- Collaborative effort of NIOSH and Stillwater Mining Co., with active participation from MSHA
- Tests were performed in May/June 2003

### OBJECTIVES

- Short-term evaluation of six diesel particulate matter filtration systems
  - DCL Blue Sky and MineX, ECS CatTrap, Engelhard, Clean Air, and Donaldson high-temperature disposable filter.
- Evaluation of the effects of fuel formulation on the emissions
  - Biodiesel (B20 and B50), Diesel D1 and D2

## Stillwater Study – Filtration Systems



Engelhard DPX on #92128



CleanAIR on #92133



DCL BlueSky on #92506

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## Stillwater Study – Filtration Systems



Donaldson on #99506



DCL MineX on #99942



ECS CatTrap on #92526

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## Stillwater Study – Fuel Formulations



Biodiesel Blends B20 and B50



CDT Platinum Plus Additive

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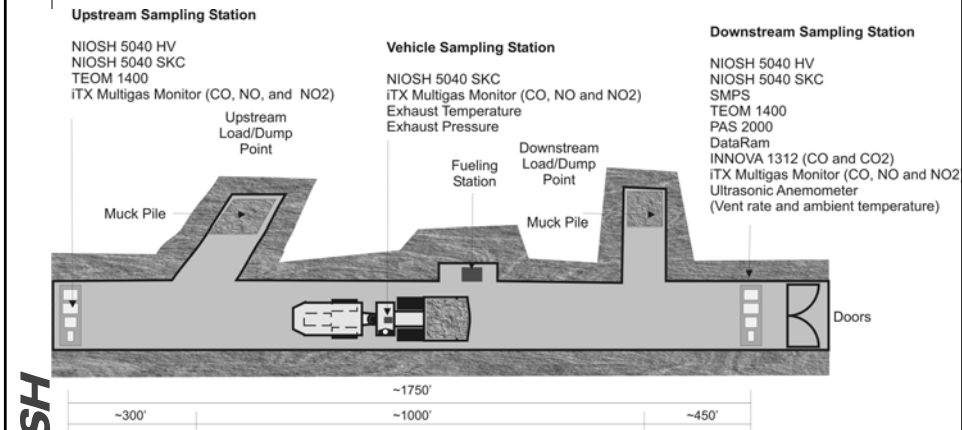
## Stillwater Study – Method

- Tailpipe emissions
  - DPM emissions were measured using :
    - Filter samples for NIOSH 5040 elemental carbon analysis
    - Bacharach smoke spot number using ECOM KL
  - Gaseous emissions (CO, NO, NO<sub>2</sub>, O<sub>2</sub>) were measured using ECOM KL and Enerac emissions analyzers
- Isolated zone
  - Concentrations of particles were measured using :
    - NIOSH 5040 carbon analysis on filter samples collected using SKC and high volume samplers
    - PAS 2000 (elemental carbon)
    - TEOM 1400 (total DPM)
    - SMPS (size distribution and number concentrations)
    - DataRam (total particles)
  - Concentrations of CO, CO<sub>2</sub>, NO, and NO<sub>2</sub>, in mine air were measured using:
    - INNOVA 1312
    - Industrial Scientific ITX

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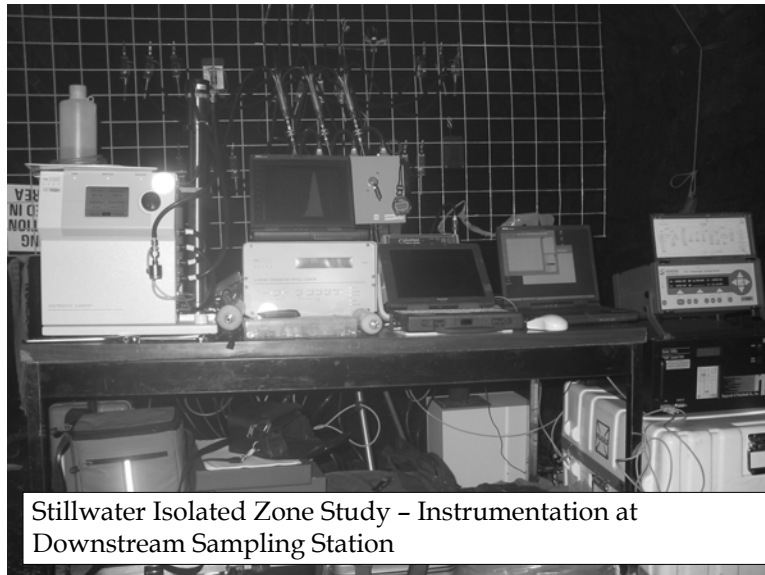
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## Stillwater Study-Isolated Zone



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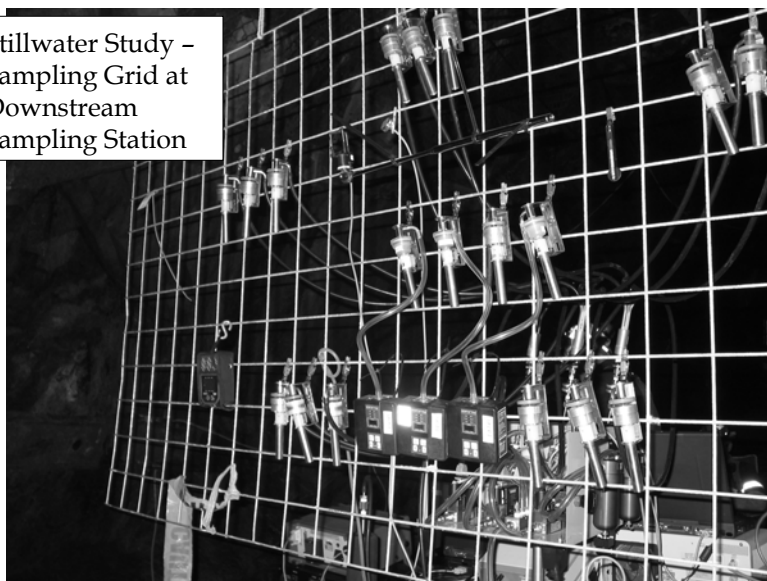


Stillwater Isolated Zone Study - Instrumentation at  
Downstream Sampling Station

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Stillwater Study -  
 Sampling Grid at  
 Downstream  
 Sampling Station



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## Stillwater Study- Findings

- \* Work in Progress!!!
- \* Available beginning of September

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## Short- vs. Long-term Field Evaluations Conclusion

- ✱ Excellent source of information
  - ✱ efficiencies
  - ✱ regeneration process
  - ✱ durability, reliability
- ✱ But, approach interpretation and extrapolation of information carefully
  - ✱ Uniqueness vs. “one-size-fits-all”
- ✱ Partnerships

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## Questions???

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